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RG:0015

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MEMORANDUM

TO: COE - UHEC conferees

FROM: Doak C. Cox

## Kaimu Beach Retreat and Sand Loss

### Introduction

The criteria proposed by the Core of Engineers in October 1974 for determining whether or not a breakwater will be built to protect the proposed enlarged Kaimu Beach were expressed in terms of sand loss rates. It appears that the criteria to be proposed by the joint conferees of the Core of Engineers and the UH Environmental Center will be expressed in the same terms, although the values may not be the same. Because of the importance given to sand loss rates by these proposals, I have corrected, updated, and extended a review of Kaimu beach retreat and sand loss estimates that I first prepared 7 November 1974 for participants in the UHEC Kaimu project review. This memorandum is the result.

### Evidences of historic retreat

The retreat of Kaimu Beach in historic times is indicated by many forms of verbal and graphic evidence. From a quantitative standpoint, the most satisfactory evidence comes from surveys of the beach profile repeated along identical sets of 8 ranges in 1968, 1972, and 1974. The sand losses and retreats of the beach over the time intervals between these surveys have been averaged over the beach face from 2 to 10 ft. above mean lower low water (mllw), and the result have been presented in Table 2 (p. 18) of the COE June 1972 Preliminary Project Report on Kaimu Beach. (The description of the procedure seems to have been garbled in the report, as noted in the UHEC 1 Feb 1973 review of that report. It is here assumed that the actual procedure was as described above.)

Repeated profile surveys on a single range were conducted by the Hawaii Institute of Geophysics, Univ. of Hawaii (HIG) in 1962, 1963, and 1971. The retreats over the time intervals between these surveys have been averaged over the profile above mllw, and the results have been presented in Table 3 (p. 19) of the June 1972 COE report. J. F. Campbell of the HIG has also estimated sand losses over the same time intervals assuming uniform retreat over a constant beach length.

Shorelines of Kaimu Beach are shown in a number of maps based on surveys predating 1968. The June 1972 COE report shows shorelines mapped in 1915 and 1940 (fig. 6, f.p. 18) and describes a shoreline mapped in 1892 (p. 17). Retreats over the time intervals between these mapping dates may be averaged over the length of the beach assuming the shorelines mapped in consecutive surveys were of identical character. The June 1972 COE report presents estimates based on the assumption and an estimate for the interval between 1940 and 1968 assuming that the 1940 shoreline was a high water line, 2 ft. above mllw. Sand loss estimates may be based on the retreat estimaes if it is assumed that the retreat is uniform at all elevations of the beach. Estimates of retreat and sand loss for the intervals 1915 to 1940 and 1940 to 1968 are shown in the June 1972 COE report (Table 2, p. 18).

An earlier COE report (Sept. 1971) mentioned shoreline maps dated 1900 and 1938. Subsequently, apparently, the dates were found erroneous, or the maps were considered inaccurate, because the COE has not used the shorelines shown in them as a basis for retreat estimation.

Other sources of evidence of beach retreat that might be quantifiable are aerial and ground photography and possibly verbal descriptions and sketches. It is possible that Kaimu Beach was photographed a century ago, and aerial photographs may have been taken of the beach nearly half a century ago. No such evidences of historic positions of the beach have been presented by the COE, however, and the following analysis relates entirely to the evidences presented by the COE and HIG.

The estimation of retreat and sand loss from such evidences is rendered uncertain by:

a. Uncertainties in the identification of the shoreline mapped in the past.

b. Incomplete indications of the position of the entire beach front from shoreline positions above.

c. Incomplete indications of the position of the entire beach front from profiles on a single range.

d. Incomplete indications of the position of the entire beach front even from its entire above-water position.

The significance of estimates of retreat rate, especially those averaged over short periods of time, is subject to further uncertainties owing to:

e. Seasonal and random departures from the general trend of retreat and sand loss resulting from departures from average conditions of wind-generated waves and tsunamis.

f. Possible changes in coastal level.

The effects of misidentification of shorelines, limitation of reliance on surveys of shorelines, single profiles, or even beach fronts above water, and of random and seasonal changes are examined in the following sections. There seems to be no evidence of post-1900 change in coastal level.

## Identification of shorelines

Shorelines mapped in Hawaii at various times by various agencies, and for various purposes include:

i) The line of mean lower low water (mllw)

ii) The line of mean sea level (msl)

iii) The line of mean high water (mhw)

iv) The kahakai (mark of the sea) as indicated by debris lines or the vegetation line.

Shorelines used by the COE in estimating beach retreat were identified as in its September 1971 Project report as those mapped in 1900 and 1938. In its June 1972 Detailed Project Report (identified as Preliminary) the COE mentioned an 1892 shoreline but used in its estimates only shorelines identified as:

1915 shoreline - survey by State of Hawaii for Executive Order #32

1940 shoreline - survey by County of Hawaii for land acquisition for Kaimu road.

1968 shoreline - Dillingham Corporation survey made for the Corps of Engineers in December 1968.

1972 shoreline - survey by Corps of Engineers in May 1972.

Data from a February 1974 survey by the Corps of Engineers is also available.

It may be assumed that the zero-elevation contours plotted from the 1968, 1972, and 1974 surveys, which were made by or for the COE, were mllw lines. Their identification is not significant, however, because for periods subsequent to 1968 the COE obtained retreat and sand-loss estimates from the changes in position of the entire beach face from +2 to +10 ft mllw.

The COE has assumed that the 1915 and 1940 shorelines were mhw lines. For reasons discussed in the Feb 1973 UHEC review of the June 1972 COE report, it seems more probable that these shorelines were kahakai. If so the mhw lines lay about 48 ft. seaward of the mapped shorelines, and the retreat estimated by the COE for the 1940 to 1968 period should be increased by about 48 feet.

## Limitations of reliance on shorelines on single profiles

Neither a shoreline nor a single profile can show the position of the entire beach front, of course. They can be used to indicate general beach retreat only under the assumptions that:

a. At the times of shoreline surveys, on the average, the profiles of the beach are the same.

b. The profiles surveyed are typical of those over the entire beach front.

The ranges of uncertainty resulting from reliance on surveys of shorelines and of single profiles could be estimated by the study of changes in beach-front configuration. Since only three multiple-profile surveys of Kaimu beach are available, such a study does not seem profitable now.

It is pertinent, however, to note that the 1940, 1968, and 1972 shorelines suggest considerable regularity to the distribution of retreat along the length of the beach during the period from 1940 to 1962.

The distribution of retreat suggests that, during this period, repeated surveys on a single profile located where HIG profile HHQ was, about one-third of the distance along the beach from its northeast end, would have indicated retreat rates about average for the beach as a whole, whereas repeated surveys on a profile about two thirds of the distance along the beach from its northeast end would have indicated retreat rates about 70 percent greater than the average. Correction could not be made to estimates of past beach front positions except by relating the changes in beach front configuration to wave conditions and hindcasting the past wave conditions.

## Effects of seasonal and random changes

The magnitude of seasonal and random changes is suggested by the following data from profiles surveyed by HIG:

| Period | | Retreat | | Sand loss | |
|---|---|---|---|---|---|
| | (mos) | Amt.(ft.) | Rate(ft/yr) | Amt.(cu.yds.) | Rate(cu.yds/yr) |
| Jun 62 - Sep 62 | 3 | 1 | 4 | 700 | 2,800 |
| Sep 62 - Jan 63 | 4 | 17 | 51 | 4,600 | 13,800 |
| Jan 63 - Apr 63 | 3 | -48 | -192 | -4,700 | 18,800 |
| Apr 63 - Jul 63 | 3 | 38 | 152 | 4,300 | 17,200 |

The retreat estimates (presented in COE 1972 Report) were made from beach profiles above mllw, according to J. F. Campbell. Some of the profiles were not surveyed to mllw, so the estimates must have involved projection. The sand loss estimates (from Campbell) were based on an assumed uniform retreat over a beach of 333 yds. constant length. The limitations of using single profiles have already been noted. However, these short-term intervals fall within the 1940-1968 period during which the retreat appears to have been fairly regular.

Because the profile surveyed by the HIG was located where the beach retreat was about average for the entire beach from 1940 to 1972, no adjustment is necessary to convert the estimates for the profile to estimates for the beach as a whole.

However, the HIG sand loss values were estimated for the entire beach front above mllw. whereas the COE values were estimated for the beach front from 2 to 10 ft. above mllw. The HIG values should then be multiplied by a factor of about 0.6 to make them consistent with the COE values. Adjusted values are shown in table 2.

Random changes in rate over longer periods of time are indicated by the following estimates:

| Period | Retreat | | | Sand loss | | |
|---|---|---|---|---|---|---|
| | (yrs) | Amt.(ft) | Rate(ft/yr) | Amt.(ft) | Rate(ft/yr) | Source |
| ? 40 - Dec 68 | 28 | 130 | 5.2 | 95,000 | 3,800 | COE |
| Jun 62 - Jul 63 | 1.12 | 8 | 7.4 | 4,900 | 4,500 | UH |
| Jul 63 - Jul 71 | 8.0 | 10 | 12.5 | 2,900 | 400 | UH |
| Dec 68 - May 72 | 3.4 | 7.6 | 2.2 | 800 | 800 | COE |
| May 72 - Feb 74 | 1.75 | 4.4 | 2.5 | 2,500+ | 1,400 | COE |

Presumably during 1940 to 1974 period, the "normal" rate of sand loss should gradually have decreased as the beach retreated and the fluctuations in rate subsequent to 1962 must be regarded as due to random variations in wave conditions over periods of one to eight years, except as the UH sand-loss values must be adjusted by a factor of 0.6 as explained above.

Recalculation of long-term changes

Using the COE data, I have recalculated the estimates of beach front position, sand volumes stored in the beach, beach retreat and retreat rates, and sand loss and loss rates presented in the June 1972 COE report, extended them back to 1892 on the basis of the approximate 1892 shoreline position reported in the 1972 report, and extended them forward to 1974 on the basis of the information recently received from the COE that the sand loss from May 1972 to February 1974 was over 2500 cu. yds. and the retreat during that period averaged 2.5 ft./yr.

The assumptions used in recalculation and extention were the following:

1) The 1892, 1915, and 1940 shorelines were kahakai, not mhw lines. The horizontal distance from the mhw line to the kahakai averaged 48 ft.

2) The loss/retreat ratios calculatable from COE data on sand loss and retreat are valid for the ranges in beach-front position assumed by the COE. Ratios were interpolated for intermediate ranges in beach front position, and extrapolated for beach-front positions earlier than 1915. These interpolated and extrapolated ratios were used to estimate sand loss from the recalculated retreat estimates.

3) Errors in the analysis of the 1968, 1972 or 1974 surveys render the retreat and loss rate calculations unreliable over the short periods 1968-72 or 1972-74. The unreliability would be reduced if the rates were calculated only over the longer period 1968-74. The unreliability is indicated by the increase in the loss-retreat ratio for 1972-74 above its value for 1968-72 although with retreat the length of beach was less in 1972-74 than in 1968-72.

The original data, ratios based on the COE analysis of the data, and the results of recalculation are shown in table 1. COE and recalculated estimates of beach-front position are plotted in fig. 1 and COE and recalculated estimates of sand volume are plotted in fig. 2. Fig. 3 relates the sand loss/retreat ratio to beach-front position.

Fig. 4 relates rates of retreat and of sand loss to beach-front position. It will be noted that the rates may have increased for the period from 1892-1915 even though the beach-front then extended far out in the bay. The 1892 data is suspect, of course, but the increase in rates of retreat and loss may have resulted as the last of the original, natural sand source was exhausted. The plots of both COE and recalculated rates suggest decreases since 1915 as the beach front retreated forward the head of the bedrock embayment. The decreases appears more regular, however, with the recalculated data. The smoothed curves are based on the recalculated data.

Projection

In table 1, I have attempted projections of:

1) Continued retreat and sand loss to the end of 1975, assuming that beach enlargement will not take place until then. For these projections I used rates of retreat and sand loss extrapolated from fig. 4.

2) The effects of the proposed 30,000 cu. yd. enlargement of the beach. The sand added will be 26,100 cu. yds. more than enough to extend the beachfront to its May 1972 position and 23,400 cu. yds. more than enough to extend it to its Dec. 1968 position, and enough to extend it to its position about August 1956 (assuming the recalculated rate of retreat from 1940 to 1968), about 37 ft. seaward of its 1972 position.

3) The renewed retreat and sand loss after enlargement, assuming no protective breakwater is constructed, and assuming no acceleration of retreat and loss rates due to the artificiality of the enlarged beach. The smooth curves of fig. 4 were used for this projection.

Short-term uncertainty ranges

To investigate the ranges of uncertainty in the rates of retreat and sand loss due to seasonal and random variations, the rates of retreat and sand loss for departures from normal rates of retreat and sand loss (the smooth curves of fig. 4) have been calculated for all short term intervals (less than 10 years) over which retreats and sand loss rates have been measured by the COE or the HIG. The HIG rates of sand loss have been adjusted as previously described to compensate for the larger area of beach front over which the loss was estimated. The results are tabulated in tables 2 and 3. The absolute departures in retreat rates are plotted against interval durations in fig. 5. The absolute departures in sand loss rates are plotted against interval durations in fig. 6. The straight lines on the plot form the outer bounds of all departures except those calculated from HIG surveys over intervals from 1962 or 1963 to 1971. The lack of fit of these latter departures to suggest that the 1971 profile may not have been correctly located.

Post-enlargement sand-loss rate estimation

I have combined in fig. 7 the seasonal and random departure ranges with the normally expected retreat and sand loss rates for the period following beach enlargement. The curves representing the sums of normal rates and departures represent the upper bounds of expectable rates averaged over various periods of time starting with the completion of beach enlargement.

The same sums, tabulated below for various periods of time, represent minimum rates to be used as criteria for determining whether a breakwater should be constructed, if the decision is to be deferred. Any smaller rates used as criteria are as likely to be exceeded in the future that the decision to build the breakwater might as well be made now.

Expectable Sand Loss Rates After Beach Enlargement
cu.yd/yr.

| mos. | yrs. | Normal | Seasonal and random departures | Total |
|---|---|---|---|---|
| 2 | 0.16 | 2,000 | 23,000 | 25,000 |
| 4 | 0.33 | 2,000 | 9,000 | 11,000 |
| 6 | 0.5 | 2,000 | 5,000 | 7,000 |
| 12 | 1 | 2,000 | 1,800 | 3,800 |
| | 2 | 2,000 | 600 | 2,600 |
| | 3 | 1,900 | 300 | 2,200 |
| | 4 | 1,900 | 200 | 2,100 |
| | 6 | 1,800 | 100 | 1,900 |
| | 8 | 1,800 | 100 | 1,900 |
| | 10 | 1,700 | 100 | 1,900 |

Table 1. Records and projections of retreat and sand loss, Kaimu Beach

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Period | | Beach | front | | Sand | | | Loss/Retreat |
| 2 | End | Duration | Final Posit. | Retreat | Rate | Final vol. | Loss | Rate | |
| 3 | Date | yrs | ft | ft | ft/yr | cu yds | cu yds | cu yds/yr | cu yds/ft |
| 4 | | | | | | | | | |
| 5 | Corps of Engineers | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | 1892 | | 250± | | | (180,000)? | | | |
| 8 | 1915 | 23 | 167 | 83± | 3.6± | 117,100 | (62,000)± | (2,700)± | (750) |
| 9 | 1940 | 25 | 37 | 130 | 5.2 | 22,100 | 95,000 | 3,800 | 730 |
| 10 | Dec 1968 | 28 | 7.6 | 29 | 1.0 | 2,700 | 19,400 | 700 | 670 |
| 11 | May 1972 | 3.4 | 0.0 | 7.6 | 2.2 | 0 | 2,700 | 800 | 350 |
| 12 | Feb 1974 | 1.75 | -4.4 | 4.4 | 2.5 | -2,500 | 2,500 | 1,400 | 570 |
| 13 | | | | | | | | | |
| 14 | Recalculated | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | 1892 | | 308± | | | 216,000±? | | | |
| 17 | 1915 | 23 | 215 | 83± | 3.6± | 152,700 | 63,000± | 2,700± | 760 |
| 18 | 1940 | 25 | 85 | 130 | 5.2 | 56,700 | 96,000 | 3,800 | 740 |
| 19 | Dec 1968 | 28 | 7.6 | 77 | 2.8 | 2,700 | 54,000 | 1,900 | 680 |
| 20 | Feb 1974 | 5.2 | -4.4 | 12 | 2.3 | -2,500 | 5,200 | 1,000 | 430 |
| 21 | | | | | | | | | |
| 22 | Univ. Hawaii HIG | | | | | | | | |
| 23 | Jun 1962 | | (10) | | | (8,500) | | | |
| 24 | Sep 1962 | 0.25 | (19) | 1 | 4 | (7,800) | 700 | 2,800 | |
| 25 | Jun 1963 | 0.33 | (2) | 17 | 51 | (3,200) | 4,600 | 13,800 | |
| 26 | Apr 1963 | 0.25 | (50) | -48 | -192 | (7,900) | -4,700 | -18,800 | |
| 27 | Jul 1963 | 0.25 | (12) | 38 | 152 | (3,600) | 4,300 | 17,200 | |
| 28 | Jul 1971 | 8.0 | (2) | 10 | 1.2 | (700) | 2,900 | 400 | |
| 29 | May 1972 | 0.83 | (0.0) | (1.8) | (2.2) | 0 | (700) | (800) | |
| 30 | Projected | | | | | | | | |
| 31 | Feb 1974 | | -4.4 | | | -2,500 | | | |
| 32 | Nov 1975 | 1.75 | -8.6 | 4.2 | 2.4 | -3,900 | 1,400 | 800 | |
| 33 | | | | | | | | | |
| 34 | Proposed beach enlargement | | | | | | | | |
| 35 | | | | | | | | | |
| 36 | Nov 1975 | | -8.6 | | | -3,900 | | | |
| 37 | Mar 1976 | | 37± | -46 | | 26,100 | -30,000 | | |
| 38 | | | | | | | | | |
| 39 | Projected post enlargement (assuming no acceler. due to artificiality) | | | | | | | | |
| 40 | | | | | | | | | |
| 41 | Mar 1976 | | 37 | | | 26,100 | | | |
| 42 | Mar 1978 | | 31.4 | 5.6 | 2.8 | 22,100 | 4,000? | 2000 | |
| 43 | Mar 1980 | | 26.2 | 5.2 | 2.6 | 18,500 | 3,600 | 1800 | |
| 44 | Mar 1982 | | 21.2 | 5.0 | 2.5 | 15,100 | 3,400 | 1700 | |
| 45 | Mar 1984 | | 16.4 | 4.8 | 2.4 | 12,100 | 3,000 | 1500 | |
| 46 | Mar 1986 | | 11.8 | 4.6 | 2.3 | 9,300 | 2,800 | 1400 | |
| 47 | | | | | | | | | |
| 48 | | | | | | | | | |
| 49 | | | | | | | | | |
| 50 | | | | | | | | | |

Table 2. Short-term retreat and sand loss, Kaimu Beach

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Period | | | Beach front position | | | | Sand volume | | |
| 2 | From | To | Duration | From | To | Average | Retreat | From | To | Loss |
| 3 | date | date | yrs | ft | ft | ft. | ft. | cu. yds. | cu. yds | cu. yds. |
| 4 | | | | | | | | | | |
| 5 | HIG | | | | | | | | | |
| 6 | Sep 62 | Jan 63 | | | | | | | | |
| 7 | Jun 62 | Sep 62 | 0.25 | 20 | 19 | 20 | 1 | 8,500 | 7,800 | 700 |
| 8 | Sep 62 | Jan 63 | 0.33 | 19 | 2 | 10 | 17 | 7,800 | 3,200 | 4,600 |
| 9 | Jan 63 | Apr 63 | 0.25 | 2 | 50 | 26 | -48 | 3,200 | 7,900 | -4,700 |
| 10 | Apr 63 | Jul 63 | 0.25 | 50 | 12 | 31 | 38 | 7,900 | 3,600 | 4,300 |
| 11 | | | | | | | | | | |
| 12 | Jun 62 | Jan 63 | 0.58 | 20 | 2 | 11 | 18 | 8,500 | 3,200 | 5,300 |
| 13 | Sep 62 | Apr 63 | 0.58 | 19 | 50 | 34 | -31 | 7,800 | 7,900 | - 100 |
| 14 | Jan 63 | Jul 63 | 0.50 | 2 | 12 | 7 | -10 | 3,200 | 3,600 | - 400 |
| 15 | | | | | | | | | | |
| 16 | Jun 62 | Apr 63 | 0.83 | 20 | 50 | 35 | -30 | 8,500 | 7,900 | 600 |
| 17 | Sep 62 | Jul 63 | 0.83 | 19 | 12 | 35 | 7 | 7,800 | 3,600 | 4,200 |
| 18 | | | | | | | | | | |
| 19 | Jun 62 | Jul 63 | 1.12 | 20 | 12 | 16 | 8 | 8,500 | 3,600 | 4,900 |
| 20 | | | | | | | | | | |
| 21 | Jul 63 | Jul 71 | 8.0 | 12 | 2 | 7 | 10 | 3,600 | 700 | 2,900 |
| 22 | | | | | | | | | | |
| 23 | Jun 62 | Jul 71 | 9.12 | 20 | 2 | 11 | 18 | 8,500 | 700 | 7,800 |
| 24 | | | | | | | | | | |
| 25 | COE | | | | | | | | | |
| 26 | | | | | | | | | | |
| 27 | Dec 68 | May 72 | 3.4 | 7.6 | 0.0 | 4 | 7.6 | 2,700 | 0 | 2,700 |
| 28 | May 72 | Feb 74 | 1.8 | 0.0 | -4.4 | -2 | 4.4 | 0 | -2,500 | 2,500 |
| 29 | | | | | | | | | | |
| 30 | Dec 68 | Feb 74 | 5.2 | 7.6 | -4.4 | 1.6 | 12.0 | 2,700 | -2,500 | 5,200 |
| 31 | | | | | | | | | | |
| 32 | | | | | | | | | | |
| 33 | | | | | | | | | | |
| 34 | | | | | | | | | | |
| 35 | | | | | | | | | | |
| 36 | | | | | | | | | | |
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| 49 | | | | | | | | | | |
| 50 | | | | | | | | | | |

Table 3. Short-term retreat and loss rates and departures from nominal rates, Kaimu Beach

| Period | | | Pos. | Retreat | | | | Sand Loss | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From date | To date | Dur yrs | Av. ft | Amt ft | Rate ft/yr | Norm rate ft/yr | Dep. ft/yr | Amt. cu yds | Rate cu yds/ft | Adj rate cu yds/yr | Norm. rate cu yds/yr | Dep. cu yds/yr |
| HIG | | | | | | | | | | | | |
| Jun 62 | Sep 62 | 0.25 | 20 | 1 | 4.0 | 2.4 | 1.6 | 700 | 2,800 | 1,700 | 1,600 | 100 |
| Sep 62 | Jan 63 | 0.33 | 10 | 17 | 52 | 2.2 | 50 | 4,600 | 13,900 | 8,300 | 1,300 | 7,000 |
| Jan 63 | Apr 63 | 0.25 | 26 | -48 | -192 | 2.4 | -194 | -4,700 | -18,800 | -11,300 | 1,700 | 9,600 |
| Apr 63 | Jul 63 | 0.25 | 31 | 38 | 152 | 2.7 | 149 | 4,300 | 17,200 | 10,300 | 1,900 | 8,700 |
| Jun 62 | Jan 63 | 0.58 | 11 | 18 | 31 | 2.2 | 29 | 5,300 | 9,100 | 5,450 | 1,300 | 5,200 |
| Sep 62 | Apr 63 | 0.58 | 34 | -31 | -53 | 2.8 | -56 | -100 | -170 | 100 | 2,000 | -1,900 |
| Jan 63 | Jul 63 | 0.50 | 7 | -10 | -20 | 2.1 | -22 | -400 | -800 | 480 | 1,100 | -620 |
| Jun 62 | Apr 63 | 0.83 | 35 | -30 | -36 | 2.8 | -39 | 600 | 720 | 430 | 2,000 | -1,580 |
| Sep 62 | Jul 63 | 0.83 | 35 | 7 | 8.4 | 2.8 | 5.6 | 4,200 | 5,100 | 3,050 | 2,000 | 1,000 |
| Jun 62 | Jul 63 | 1.12 | 16 | 8 | 7.2 | 2.3 | 4.9 | 4,900 | 4,400 | 2,600 | 1,400 | 1,200 |
| Jul 63 | Jul 71 | 8.00 | 17 | 10 | 1.2 | 2.1 | -0.9 | 2,900 | 360 | 220 | 1,100 | -900 |
| Jun 62 | Jul 71 | 9.12 | 11 | 18 | 2.0 | 2.2 | -0.2 | 7,800 | 860 | 520 | 1,300 | -780 |
| COE | | | | | | | | | | | | |
| Dec 68 | May 72 | 3.4 | 4 | 7.6 | 2.2 | 2.1 | 0.1 | 2,700 | 800 | | 1,100 | -300 |
| May 72 | Feb 74 | 1.8 | -2 | 4.4 | 2.5 | 2.0 | 0.5 | 2,500 | 1,400 | | 900 | -500 |
| Dec 68 | Feb 74 | 5.2 | 1.6 | 12.0 | 2.3 | 2.0 | 0.3 | 5,200 | 1,000 | | 1,000 | 0 |

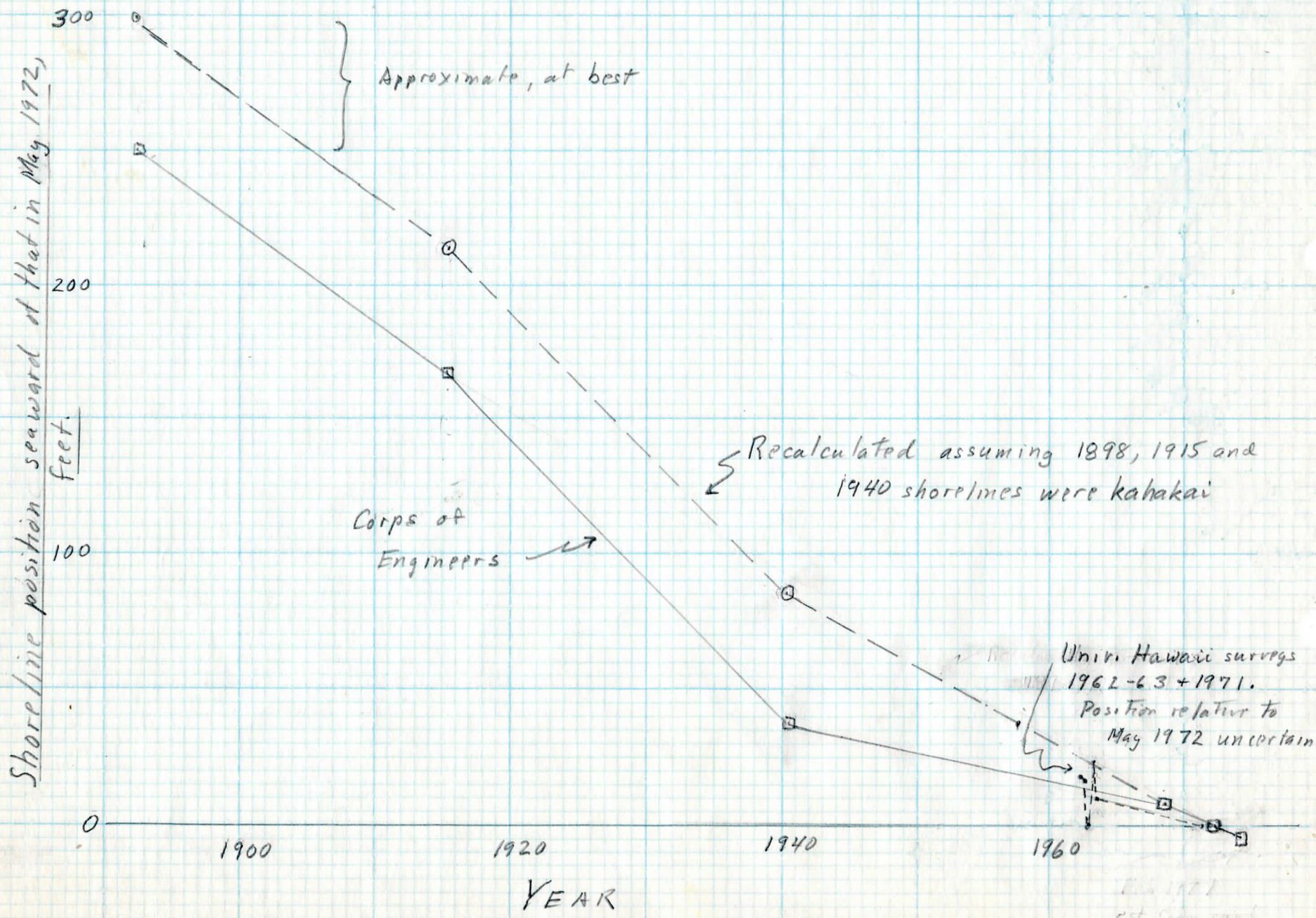



Figure 1. Historic beachfront retreat, Kaimu Beach

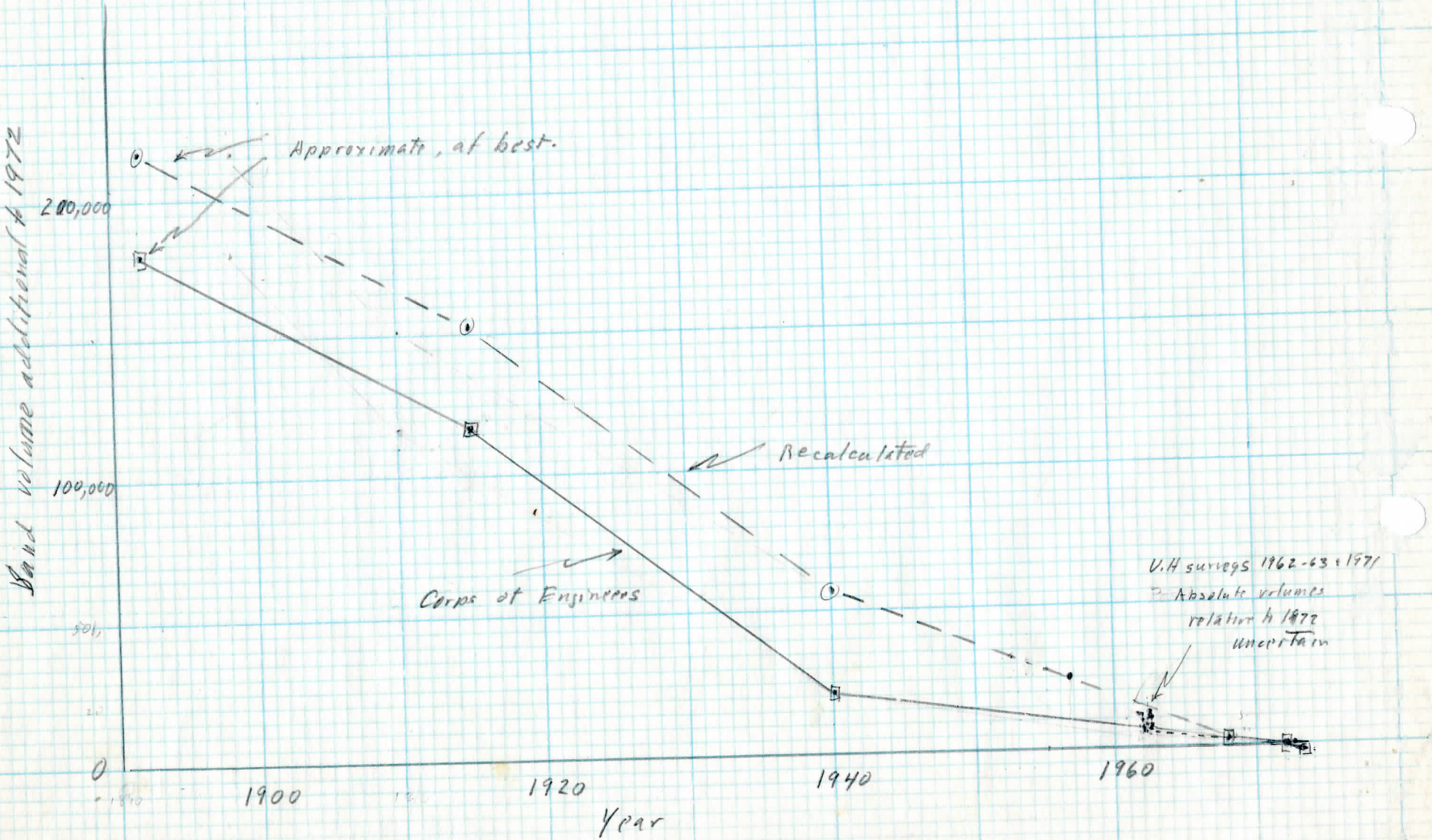



Figure 2. Historic sand loss, Kaimu Beach

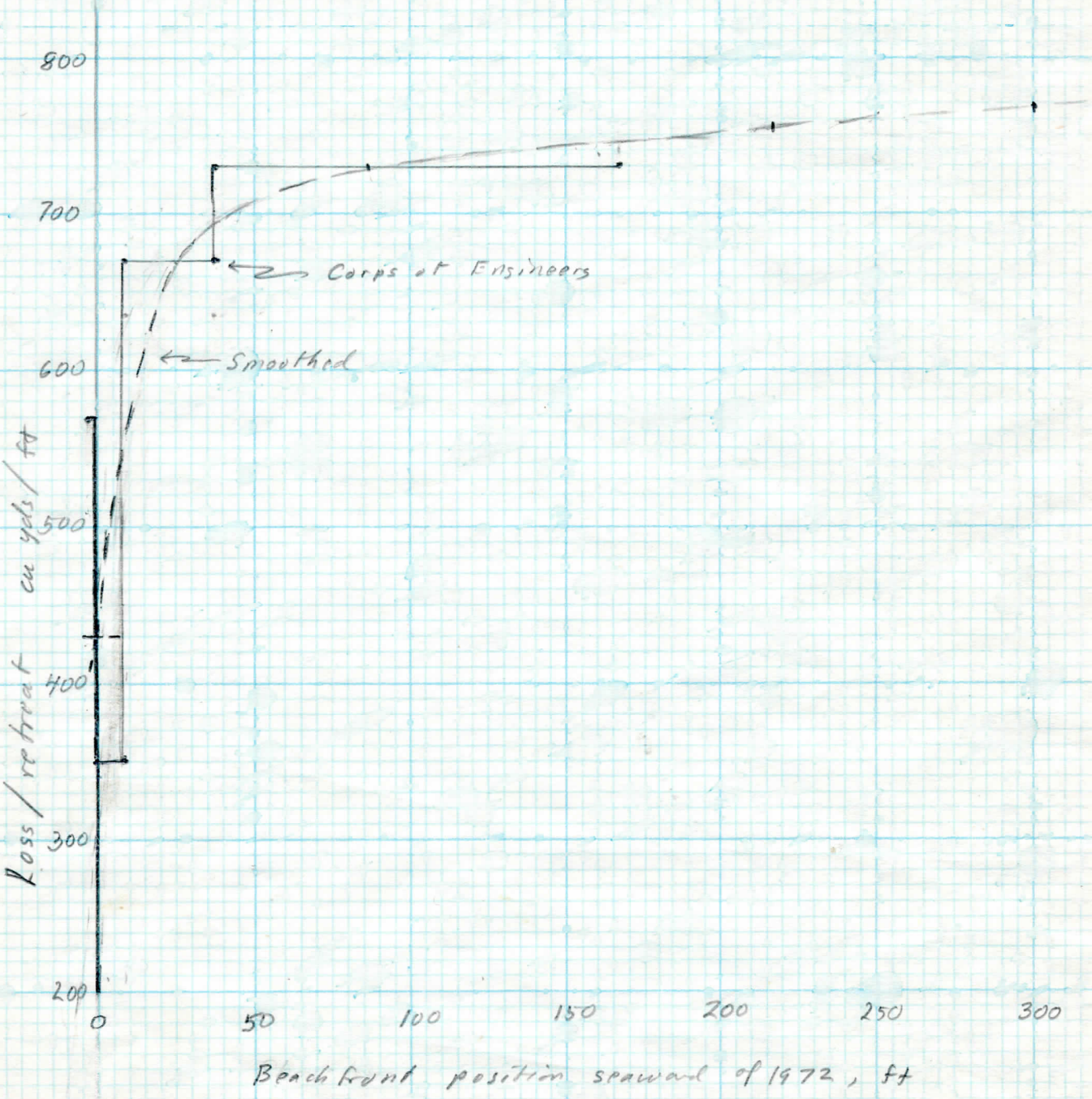



Figure 3. Sand loss/retreat ratio vs beachfront position, Kaimu Beach

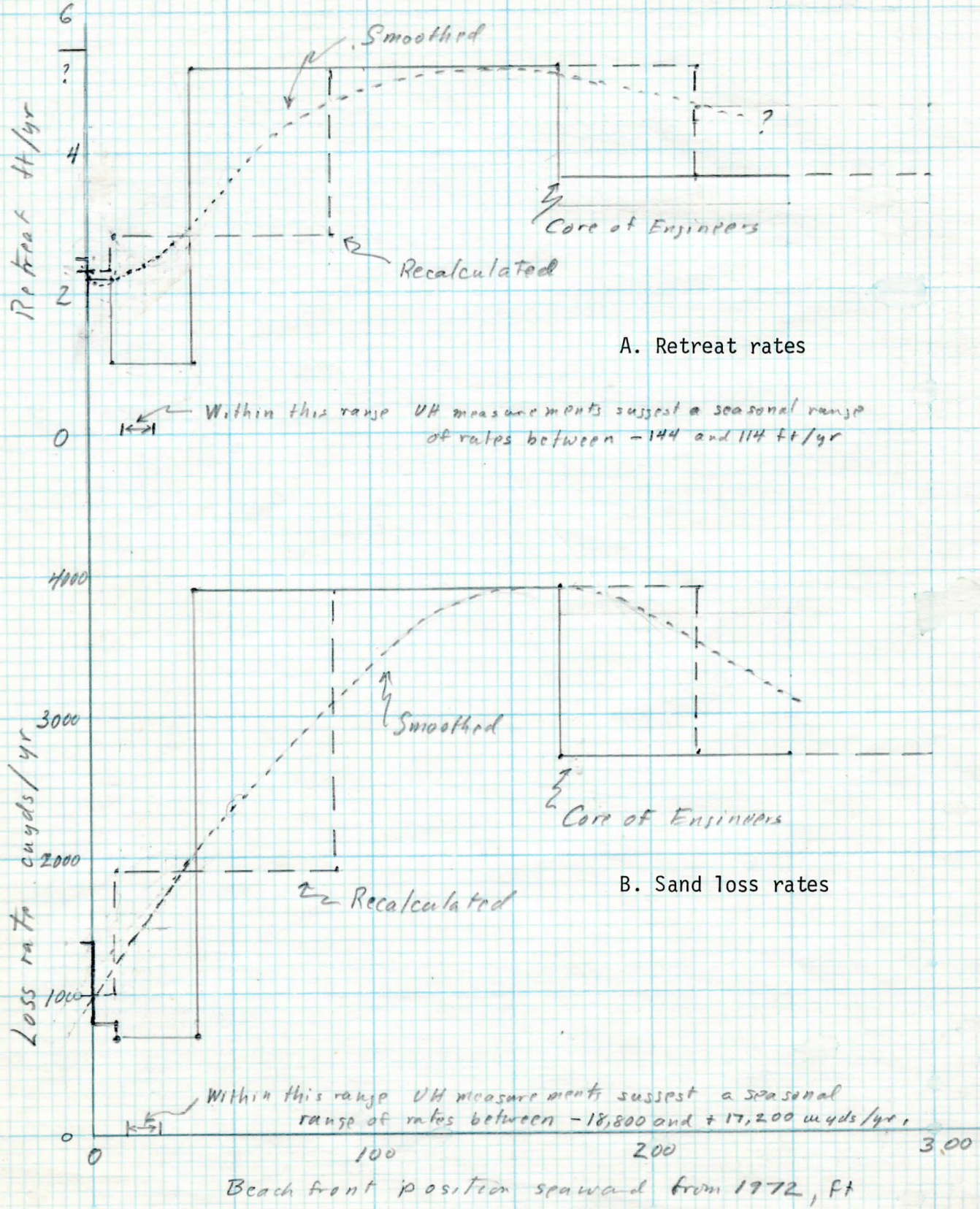



Figure 4. Retreat and sand-loss rates vs beachfront position, Kaimu Beach

Fig. 5. Absolute retreat rate departures from normal vs. time intervals

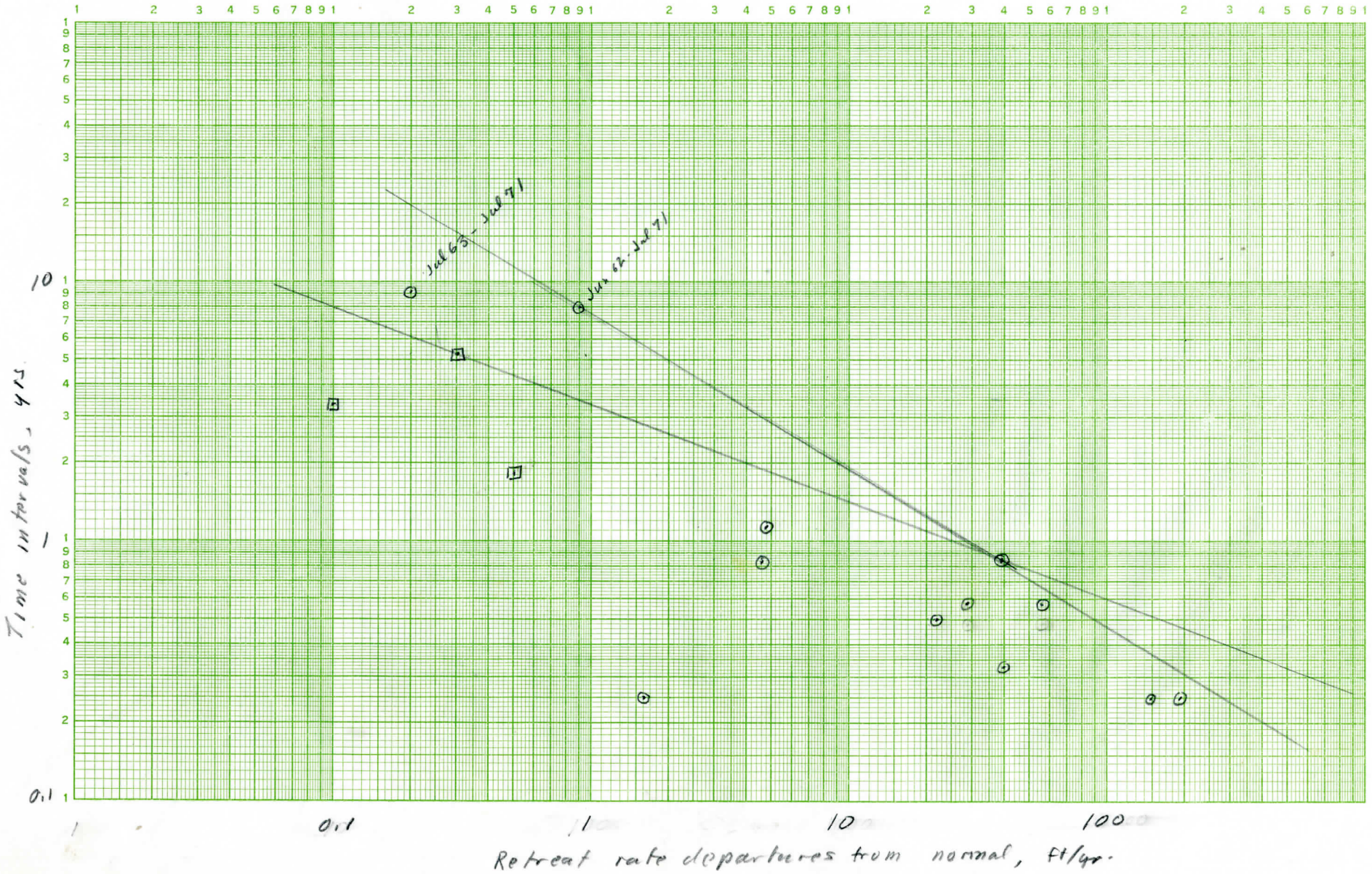
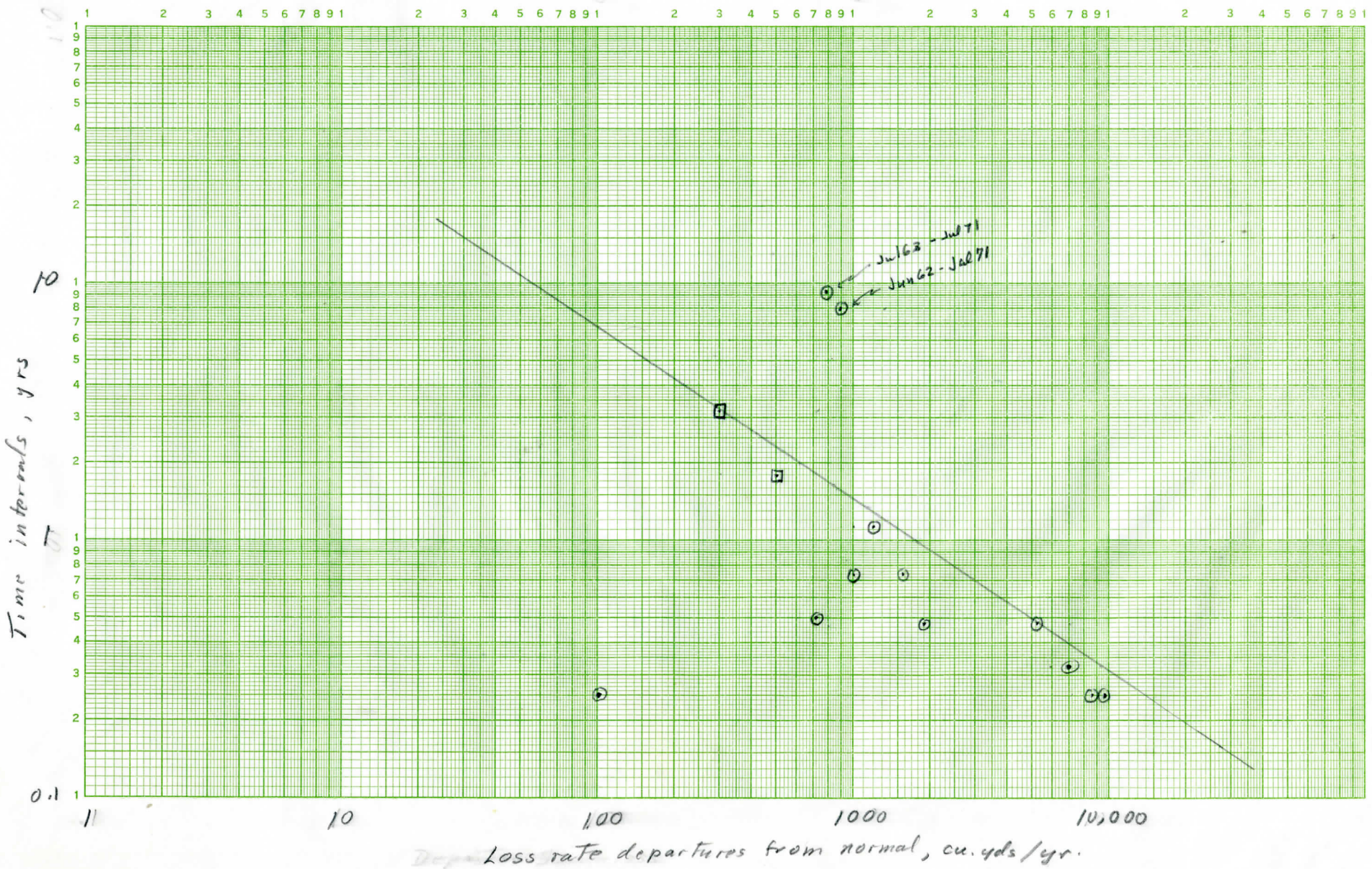


Fig. 6. Absolute sand-loss rate departures from normal vs. time intervals



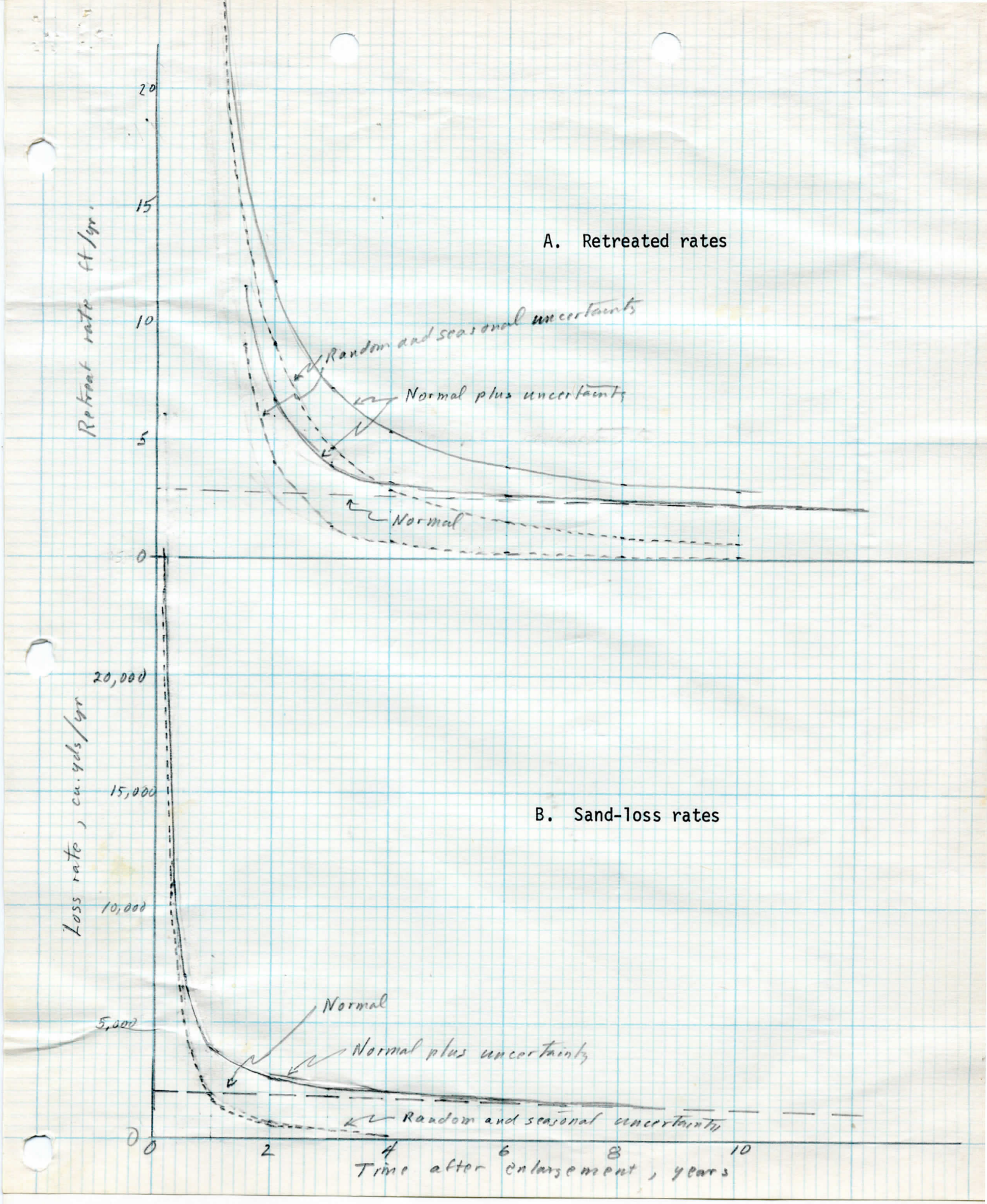



Fig. 7. Expectable retreat and sand-loss rates after enlargement, Kaimu Beach